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CERTIFICATE

This certificate is issued in support of an application for Patent registration in a country outside New Zealand pursuant to the Patents Act 1953 and the Regulations thereunder.

I hereby certify that annexed is a true copy of the Provisional Specification as filed on 30 July 2002 with an application for Letters Patent number 520450 made by MOORING SYSTEMS LIMITED.

Dated 6 August 2003.

PRIORITY DOCUMENT
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Neville Harris

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Commissioner of Patents

520450

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James & Wells ref.: 41916/24

Patents Act 1953

PROVISIONAL SPECIFICATION

Method of Controlling a Mooring System

We, Mooring Systems Ltd of Unit 6, Amuri Park, 404 Barbadoes Street, Christchurch, New Zealand, a New Zealand company, do hereby declare this invention to be described in the following statement:

TECHNICAL FIELD

The present invention relates to the control of ship mooring and to systems for monitoring mooring loads applied to a ship, in particular the invention relates to the control of a mooring system employing mooring robots having an attractive attachment element for engagement with a surface for making fast the ship.

BACKGROUND ART

This invention relates to a process for mooring a ship at a terminal such as a dock in which the ship is held towards the terminal with mooring loads provided by separate mooring robots. Automated systems such as this are described, for example, in WO 0162585 and have a number of advantages over conventional mooring employing mooring lines.

When the ship is approaching the terminal the mooring robots are able to provide large forces within a reasonably short time to counter the significant dynamic forces and stop movement of the ship or bring it under precise control into the desired position relative to the terminal. However, a problem which any mooring system must counter is the effect of water currents and wind that tend to bring the ship out of contact with the mooring, and this is an important safety consideration in the design of robotic systems employing attractive attachment elements, such as vacuum cups. In order to provide a high level of safety, while avoiding over-design and excessive redundancy, it will be understood that there is a need for the operation of these systems to be monitored and controlled.

In conventional ship mooring employing mooring lines, various methods have been

proposed for monitoring the mooring loads and controlling the mooring system to avoid catastrophic failure. For example, the magnitude of the tensile loads in the mooring lines have been monitored to control automatic mooring winches. A difficulty with this method is that of providing an indication of the magnitude of the total mooring load acting upon the ship, which requires that the direction of the loads provided by the mooring line also be determined. These known systems are also unable to provide mooring load data while the vessel is moving relative to the terminal.

Moreover the accuracy achievable with these prior art systems is limited by the properties of the mooring lines, which may interfere with one another or with bollards etc to produce anomalous effects which cannot be readily measured.

It is an object of the present invention to address the foregoing needs and problems or at least to provide the public with a useful choice.

Further aspects and advantages of the present invention will become apparent from the ensuing description which is given by way of example only.

DISCLOSURE OF INVENTION

According to one aspect of the present invention there is provided a method of controlling a mooring system, the method including the steps:

(a) providing a mooring system including at least one mooring robot for releasably fastening a vessel, the mooring robot having an attractive attachment element fastened thereto for releasable engagement with a surface for making fast the

vessel, the robot providing power-actuated translational movement of the attachment element in at least a vertical and an athwartship direction generally perpendicular thereto;

(b) mooring the vessel with the mooring system;

(c) measuring the attractive force between the surface and the attachment element;

(d) monitoring at least the athwartship force applied to the robot in the athwartship direction;

(e) controlling the attractive force between the surface and the attachment element proportionally to the athwartship force, and

(f) providing an alarm when the athwartship force approaches a holding capacity of the attachment element.

Preferably the athwartship force is continuously monitored using transducers fixed to the robot, with a corresponding signal being transmitted to the bridge of the moored vessel where the athwartship force is displayed. The attractive force may also be transmitted to and displayed upon the bridge of the vessel. The athwartship force, attractive force and alarm may be transmitted (e.g. to a central monitoring station or the port authorities) for providing remote monitoring of the performance of the mooring robot.

It will be understood that the alarm indicates an approaching or imminent failure of the mooring in a tensile mode allowing the vessel to break free, and that the holding capacity of the attachment element is a maximum tensile load acting to separate the attachment element from the surface.

Preferably when the athwartship force exceeds a first threshold the mooring robot operates in a safe mode wherein the attractive force between the surface and the attachment element is maintained at a maximum.

Preferably the mooring system includes a plurality of centrally controlled mooring robots as described above, and when the athwartship force measured on any one mooring robot exceeds a second threshold, then the mooring robots are controlled to distribute the respective athwartship forces exerted by each robot optimally in accordance with the respective holding capacities of the attachment elements. For example, two pairs comprising a fore pair and an aft pair of mooring robots are provided in a preferred embodiment of the system. When the athwartship force measured on one mooring robot in the aft pair exceeds the second threshold, and both robots in the aft pair have the same holding capacity, then the athwartship force measured on the other mooring robot of the aft pair is increased by actuation of the robot to evenly distribute the respective athwartship forces exerted by each robot.

Preferably the mooring robots are fixed to a terminal, the terminal being either a fixed or floating dock (or a second vessel) having fenders fixed thereto for engagement with the hull of the moored vessel, such that the robots are actuated to press the hull of the vessel to engage with fenders so as to cause friction to avoid unintended fore-and-aft movement of the ship with respect to the terminal. Although some vertical movement of the ship relative to the mounting will be unavoidable due to movements of the ship caused by tidal forces and loading and unloading, the attachment element is not released to reposition it to accommodate this movement. In the limiting case the attachment element will slide

while maintaining contact with the surface to which it is fastened.

According to another aspect of the present invention there is provided a method of controlling a mooring system, the method including the steps:

(a) providing a mooring system including at least one mooring robot for releasably fastening a vessel, the mooring robot having an attractive attachment element fastened thereto for releasable engagement with a surface for making fast the vessel, the robot providing power-actuated translational movement of the attachment element in three dimensions, along three mutually perpendicular axes comprising a longitudinal axis, a vertical axis and an athwartship axis;

(b) mooring the vessel with the mooring system;

(c) monitoring an athwartship force applied to the robot in the athwartship direction, and

(d) monitoring a longitudinal force applied to the robot in the longitudinal direction.

Preferably the athwartship and longitudinal forces are measured by transducers fixed to respective linear actuators for actuating movement of the robot in the athwartship and longitudinal directions. The values of the athwartship and longitudinal forces are preferably displayed in real time on the bridge of the ship.

Controlling the operation of a mooring system according to the method of the present invention maximizes its performance, reduces energy consumption and improves safety. By providing an alarm as capacity is approached, together with feedback of the capacity and the magnitude and direction of the applied loads, it allows the master of the vessel to

take the most appropriate action to ensure the safety of the vessel in extreme conditions.

BRIEF DESCRIPTION OF DRAWINGS

Further aspects of the present invention will become apparent from the following description which is given by way of example only and with reference to the accompanying drawings in which:

Figure 1 is a pictorial view of a preferred embodiment of a mooring robot for performing the method of the present invention;

Figure 2 is an exploded view of the mooring robot of Fig. 1;

Figure 2a shows part of the mooring robot of Fig. 2 from a rotated viewpoint;

Figure 3 is a side elevation of the mooring robot of Fig.1; and

Figure 4 is a plan view illustrating the deployment of mooring robots for performing the method of the present invention.

BEST MODES FOR CARRYING OUT THE INVENTION

Referring to Figs. 1 and 2 of the drawings, a device for performing the method of the present invention comprises a mooring system incorporating a plurality of mooring robots 100, as described in our PCT International Application No. PCT/NZ02/00062. The description of the mooring robots and mooring system in this application is hereby incorporated by reference. Other preferred embodiments of a mooring system (not illustrated) for performing the method of the present invention include a mooring system wherein mooring robots 100 are fixed to the vessel allowing the vessel to be readily fastened to a bearing plate fixed to the dock 110 or to another vessel. It will be

appreciated, however, that this, as well as other robot type mooring devices, may be employed for performing the method of the present invention.

Each mooring robot 100 is mounted to a dock 110, fixed adjacent to a front mooring face 112 of the dock. The mooring robot 100 includes a pair of vacuum cups 1, 1', which are maintained substantially parallel to the plane of the front mooring face 112 for engagement with the hull of a vessel. The mooring robot 100 is capable of positioning the vacuum cups 1, 1' in three dimensions, referred to herein as "vertical", "longitudinal" and "athwartship", wherein "longitudinal" refers to a direction perpendicular to the vertical axis and parallel to the longitudinal axis of the moored vessel or the front mooring face 112 of the dock.

A parallel arm linkage provides for movement of the vacuum cups 1, 1' in the athwartship direction, and includes parallel upper and lower arms 2, 2' connected between a pair of columns 114 of the framework 113 and a vertical guide 10. The arms 2, 2' are fixed to the framework 113 for pivoting movement about respective longitudinally extending axes, each arm 2, 2' being fixed in bearings 3 fastened to the columns 114. Likewise, a pivoting connection is provided between the arms 2, 2' and the guide assembly 10. Power actuation of the athwartship movement is provided by a hydraulic ram 4, which is also pivotably connected between the framework 113 and the guide 10.

A carriage 11 engages with the vertical guide 10 to provide vertical movement. The guide 10 is an assembly including a pair of parallel elongate guide members 5, 5' connected by cross members 6, 7 and 8. Fixed to the top cross member 6 are two hydraulic motors 9, 9'

which are each connected to a loop of chain 20 which extends parallel to each of the guide members 5, 5' and is connected to the carriage 11 for power actuated raising and lowering thereof.

A sub-frame 12 to which the vacuum cups 1, 1' are mounted is slidably engaged with the carriage 11 for longitudinal movement of the vacuum cups 1, 1'. The carriage 11 includes vertical channels 21, 21' for engagement with the guide members 5, 5' and a longitudinally extending track 22 in which the sub-frame 11 is slidingly received. Longitudinal movement of the vacuum cups 1, 1' is power actuated by hydraulic ram 23 fixed in the track 22, the ram 23 being a double-acting type with a continuous piston rod 24 extending from both ends of the cylinder 23.

Each mooring robot 100 also includes a hydraulic power pack (not shown) mounted inside the framework 113 and associated controls (not shown). A vacuum pump (not shown) provides means for drawing a vacuum in the vacuum cups 1, 1'. Vacuum and hydraulic connections are by means of flexible hoses (not shown). For control of the robot, movement of the vacuum cups 1, 1' in each of the dimensions is measured by respective linear position sensors (not shown). This position information together with hydraulic pressures in the rams 4 and 23 and vacuum measured in each vacuum cup 1, 1' is monitored by a robot control computer (not shown) and transmitted as required to a remote controller (not shown) which, in the preferred embodiment controls a mooring system comprising at least two pairs of mooring robots 100.

Referring to Fig. 3, to make fast a ship, the vacuum cups 1, 1' are extended from the front

mooring face 112 when a vessel 200 approaches to engage a planar section of the hull. The vacuum cups 1, 1' are evacuated when contact with the hull is made in orderto fasten to the ship. The vacuum pump is run until a (differential) vacuum of 80% is obtained at the vacuum cups, before actuating the mooring robot 100 to move the ship to the desired moored position. When the desired moored position is reached the vacuum pump may be stopped, with a vacuum accumulator (not shown) in the line to the vacuum cups 1, 1' maintaining the vacuum. The vacuum is continuously monitored and if it falls to 60%, the vacuum pump is again started, so that vacuum is maintained between 60-80% under normal operating conditions.

Each mooring robot 100 maintains the ship, within certain limits, in the moored position in response to changing conditions of wind, tide, swell and displacement. On attaining the desired moored position the hydraulic pump (not shown) is stopped and an accumulator (not shown) is cut into the lines to the rams 4 and 24, thus providing a resilient action. When displaced from the predefined moored position longitudinally or athwartship by external forces, the accumulator is pressurised and provides hydraulic pressure to the rams 4, 23 tending to restore the ship to the moored position. The hydraulic motors 9, 9' (or linear actuators, if used) for raising and lowering the vacuum cups 1, 1' are switched into a free-floating mode allowing the carriage 11 (and thus the vessel 200) to rise and fall with the tide, state of loading, etc.

The critical mooring forces are those caused by current or wind that have a component in the athwartship direction acting to separate the vessel 200 from the robots 100. These loads are monitored by each robot 100, using a transducer connected to the ram 4. When

the tensile load applied to the ram 4 exceeds a first threshold then the vacuum pump is run continuously to attain a maximum attachment force with a vacuum in excess of 80%. Correspondingly, when the tensile load measured in the ram 4 falls below this first threshold value, then the vacuum pump is stopped.

As shown in Fig. 5, a mooring system in the illustrated embodiment includes two pairs of mooring robots 100 each having an independent hydraulic and vacuum supply, the robots 100 being installed between energy-absorbing fenders 50 placed at intervals along the front face of the dock 12. Each of the mooring robots 100 is connected by a wireless link to a remote control unit mounted aboard the vessel 200. The remote control transmits a signal to each mooring robot 100 to control its position and operation, and receives feedback of actual position and operating conditions, including the magnitude and direction of the mooring loads in the athwartships direction. By displaying this information in the bridge of the vessel the master is able to take actions to reduce or redistribute the loads and he receives instant feedback upon the effects of these actions.

Under most conditions the operation of the mooring robots 100 is coordinated, for example, when mooring and unmooring the ship, or when performing vertical or horizontal stepping movements, as described in WO 0162584. Monitoring of hydraulic pressures in the rams 4, 23 and vacuum in the vacuum cups 1, 1' allows the performance of the system to adjusted to attain optimum use of each mooring robot 100. In increasingly severe conditions the tensile load applied to the ram 4 may exceed a second threshold, then the mooring robots in each pair are controlled to distribute the respective athwartship forces exerted by each robot 100 optimally in accordance with the respective

holding capacities of the vacuum cups. If the force applied to the robots 100 also has a longitudinal component, them the robots 100 are controlled to press the hull of the vessel 200 to engage the fenders 5.

Under normal conditions when the mooring robot 100 approaches the extent of its vertical travel the system initiates a stepping sequence moving each mooring robot 100 alternately in a stepwise manner, however in this highly loaded state, stepping is prevented to ensure security of the vessel.

An alarm is indicated when the system is approaching its holding capacity as determined by the tensile loads in each robot approaching the holding capacities of their respective vacuum cups, thus allowing the ship's captain to take emergency action. Optionally the master may set an "alert" at some level below this alarm level.

The total mooring force applied to the vessel 200 by each robot 100 when the hull is free from the fenders 50 is the sum of the athwartship and longitudinal components as measured through the transducers fixed to the rams 4 and 23 respectively. By knowing the magnitude and direction of this total mooring force the master is able to determine the best response to any situation when an alarm is indicated.

The mooring system performance is also sent to a remote station. Time varying behavior of the vacuum in the vacuum cups and the mooring loads and directions as determined from the pressure measurements made at the rams 4 and 23 are monitored and recorded. Other data is also monitored and recorded, including the position of the vacuum cups.

Optionally, environmental measurements of wind and current speed and direction may also be simultaneously monitored and recorded, allowing vessel-specific data to be accumulated for load prediction.

Aspects of the present invention have been described by way of example only and it should be appreciated that modifications and additions may be made thereto without departing from the scope thereof.

MOORING SYSTEMS LTD
by their authorised agents
JAMES & WELLS
per:

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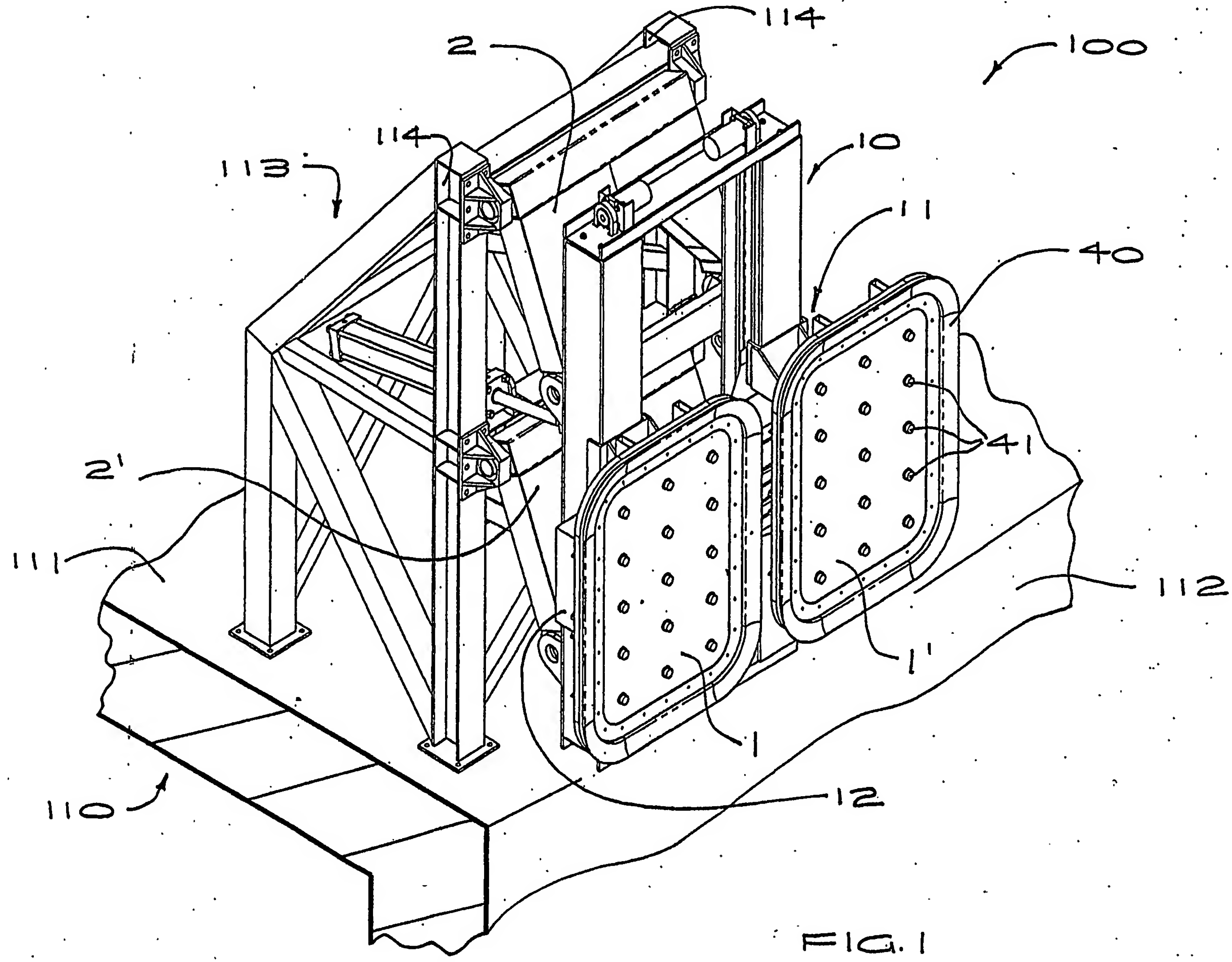

FIG. 1

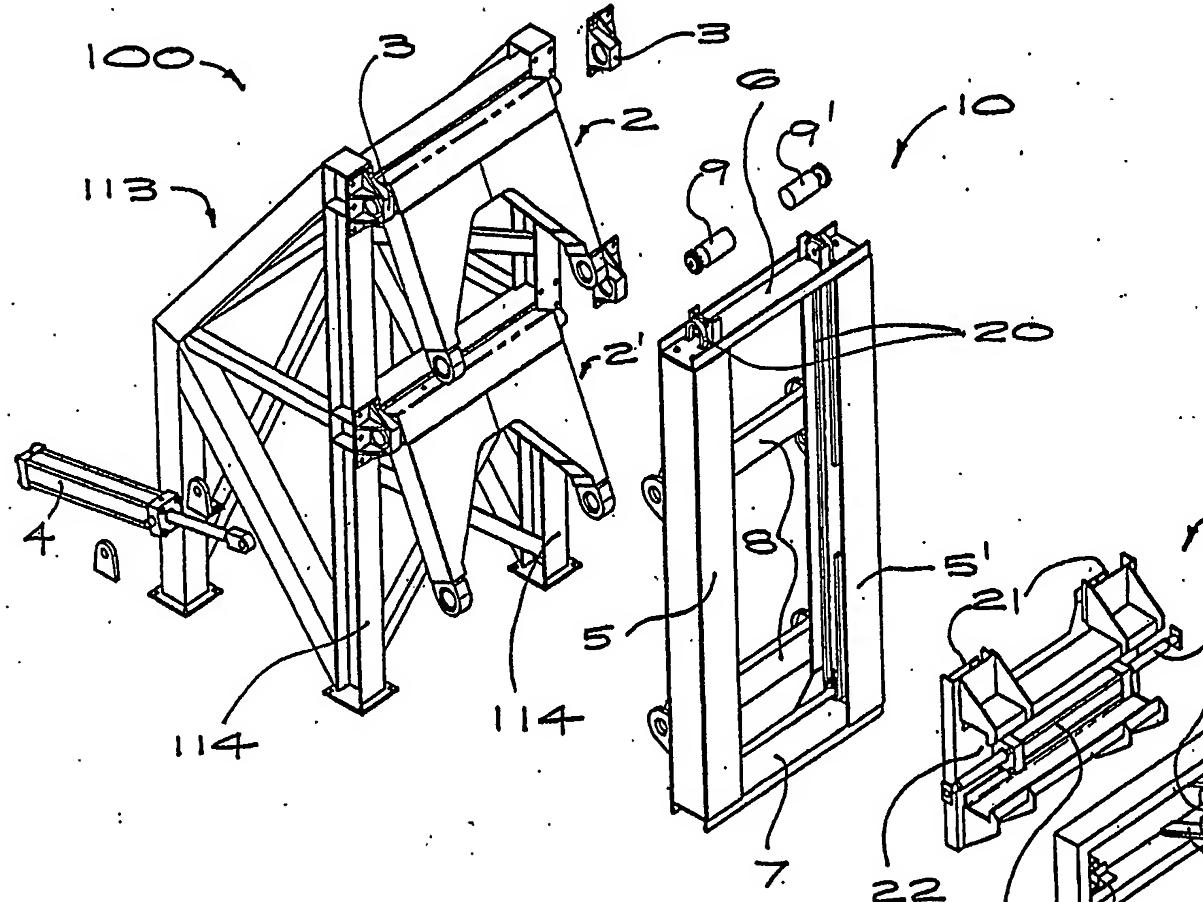
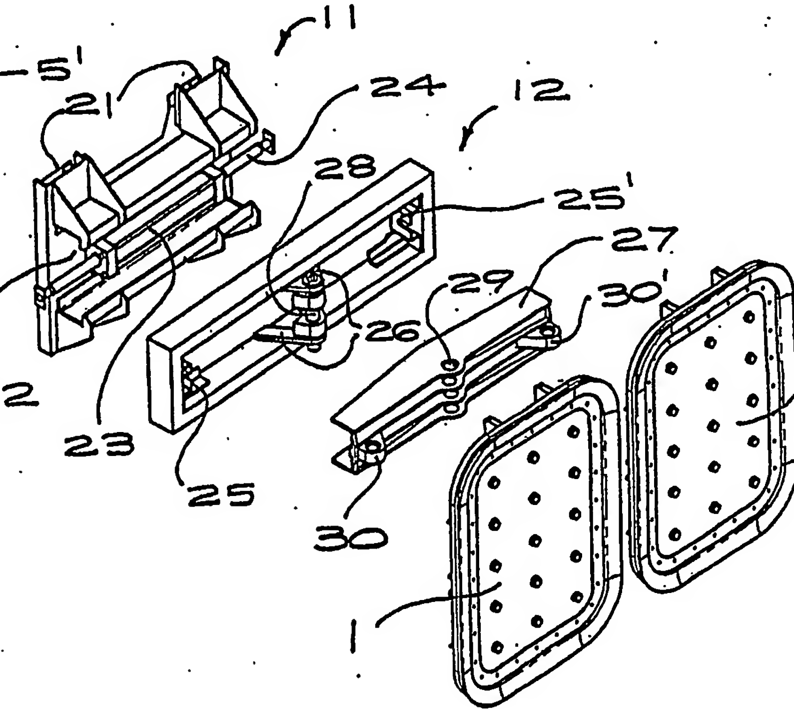

FIG. 2

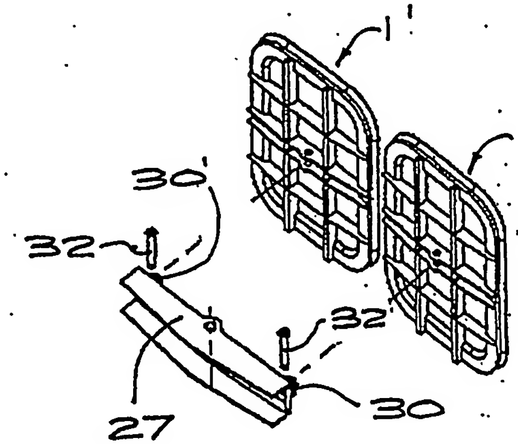

FIG. 29

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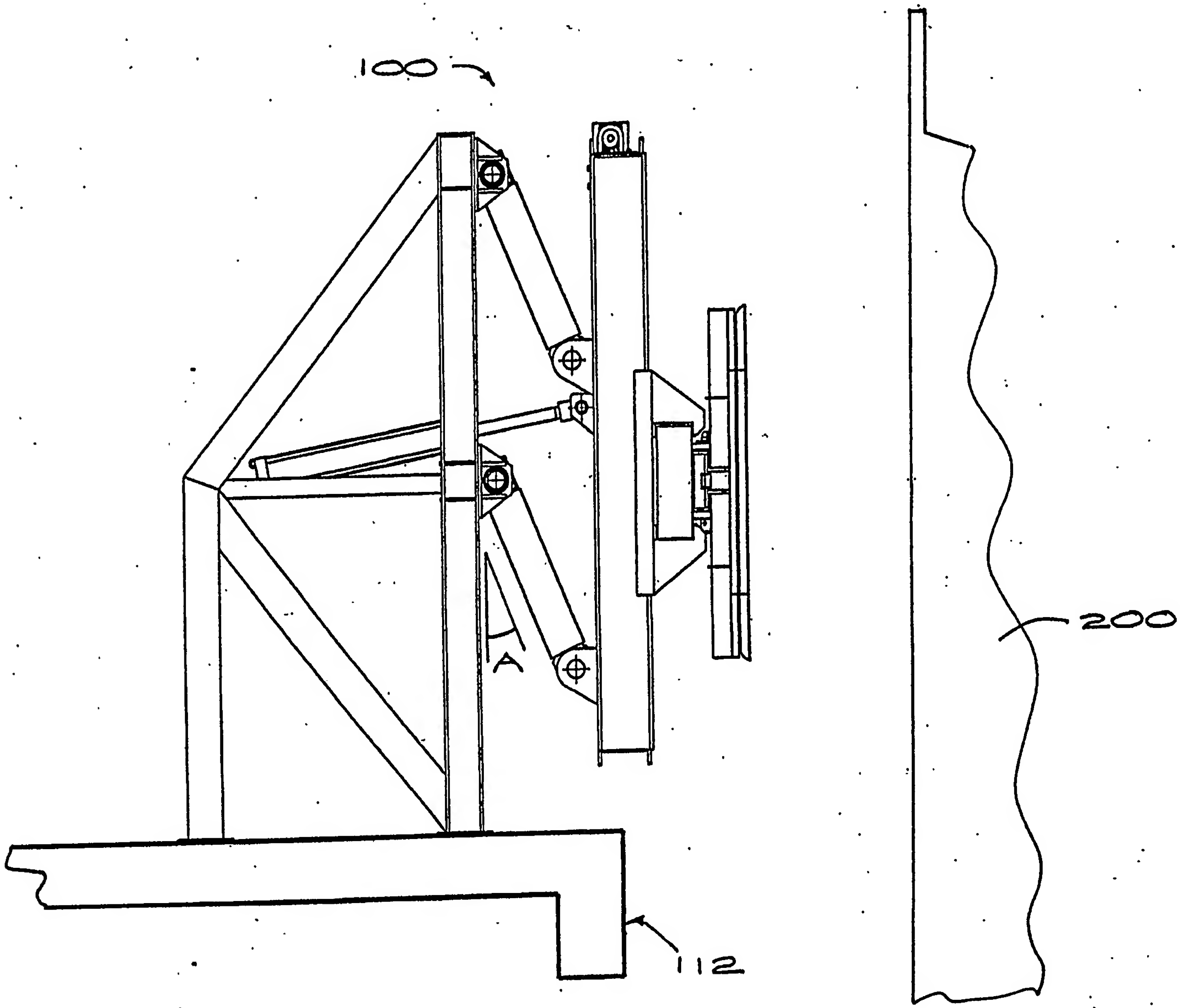

FIG. 3

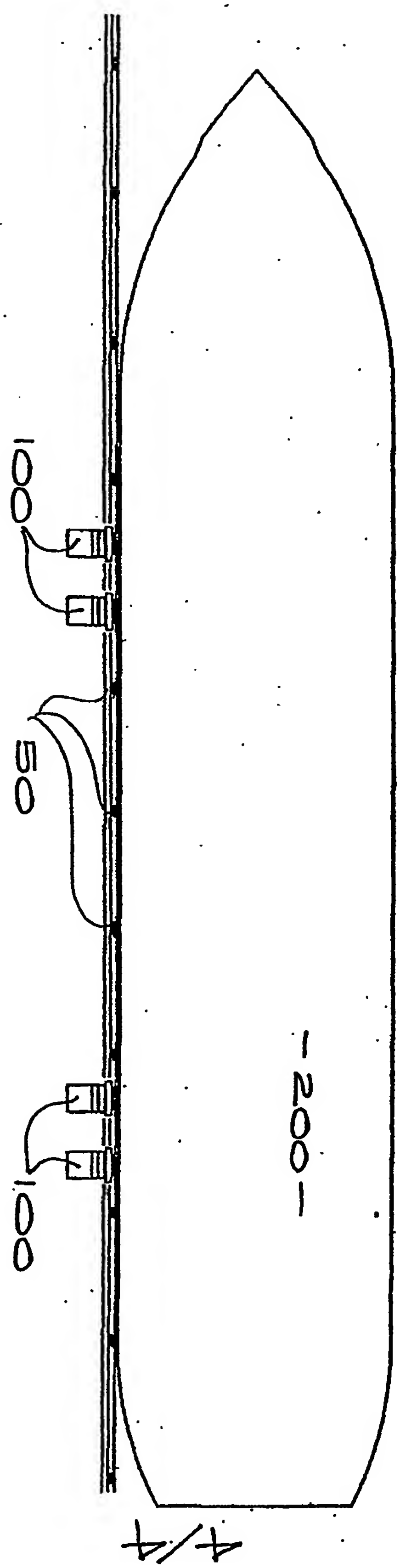

FIG. 4